DOCUMENT RESUME

ED 084 867 EM 011 690

AUTHOR Tidball, Charles S.; Bon, Bruce B.
TITLE Educational Time-Sharing on a Minicomputer.
INSTITUTION George Washington Univ., Washington, D.C. School of Medicine.
PUB DATE 73
NOTE 22p.; Paper presented at ADCIS Summer Meeting (Ann Arbor, Mich., 1973); Appendics from DECUS Proceedings, 1972 and 1973

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS Computer Assisted Instruction; *Computer Based Laboratories; *Computer Programs; Computers; *Computer Science; Computer Storage Devices; Higher Education; *On Line Systems; Program Descriptions; Programing; Programing Languages; *Time Sharing
IDENTIFIERS Digital Equipment Corporation; FOCAL Language; LINC tape; Minicomputers; MTS 12; *Multi Language Time Sharing System; PDP 12 Computer

ABSTRACT

A multi-language, time-sharing system (MTS-12) has been developed for the PDP-12, a Digital Equipment Corporation laboratory computer. This low-cost, core-resident system features program storage on LINC tape (3/4" magnetic tape on a 4" reel), access to the high-level interpreted FOCAL language, and a special variable storage in the user buffer area which permits string handling, answer storage and other housekeeping functions. Although less convenient than special purpose languages, FOCAL has direct command capability which is easy to learn and which provides full mathematical support. No specific author mode is available, but FOCAL is quite simple and can be used without programer assistance. A MODIFY command provides online program correction, and file protection is available to control use of this feature. With this system, sophisticated teaching programs can be presented to three simultaneous users in only 12k of 12 bit core. The system is expandable, but is especially suited for small-scale use with the mainframe unattended, when the PDP-12 might not be in use. (Author)

ED 084867

EDUCATIONAL TIME-SHARING ON A MINICOMPUTER

(A paper presented at the 1973 ADCIS Summer Meeting in Ann Arbor, Michigan)

Charles S. Tidball and Bruce B. Bon
Department of Physiology
George Washington University Medical Center, Washington, D.C.

ABSTRACT

We have developed MTS-12, a Multi-language, Time-sharing System for the PDP-12, a popular laboratory computer manufactured by the Digital Equipment Corporation. This low-cost, core-resident, time-sharing system features program storage on LINCtape (3/4" magnetic tape on a 4" reel), access to the high-level, interpreted, language FOCAL, and special variable storage in the user buffer area which permits string handling as well as answer storage and other housekeeping functions. Although less convenient than special purpose CAI languages, FOCAL has a direct command capability which is easy for the student to learn and provides full mathematical support. No specific author mode is available but FOCAL is quite simple and can be used directly by faculty members without requiring programmer assistance. A powerful Modify command provides on-line program correction; file protection is available to control the use of this feature. With this system, sophisticated teaching programs can be presented to three simultaneous users in only 12K of 12 bit core. The system can be expanded to more users but is especially suited for small-scale use with the mainframe unattended, on evenings and weekends when the PDP-12 might ordinarily not be in use.

EM 011 690

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

FILMED FROM BEST AVAILABLE COPY

The paper entitled "Educational Time-sharing on a Minicomputer" which was presented at the 1973 ADCIS Summer Meeting in Ann Arbor, MI was never written out as such. Some of the material was previously published in two technical articles which appeared in DECUS Proceedings. Since that publication is not readily available to persons in the education field, the two papers have been appended in their entirety. The remainder of the presentation can be derived from the lantern slides which were projected; camera copy for these has been included except where the slide was taken from the appended articles. The list of the lantern slides below was added to indicate the actual order of presentation. Finally, it should be acknowledged that at this writing (November 13, 1973), yet a third version of MTS-12 is being developed. Readers who have a genuine interest in implementing this time-sharing system on their own equipment, are encouraged to contact the authors to obtain the most up-to-date information on how to proceed.

Slide	Title
1	Introduction
2	Comparison of Four Time-Sharing Systems for the PDP-12
3	Growth of a Time-Sharing System versus Mainframe Cost per Simultaneous User
4	Comparison of MTS-12A and MTS-12B
5	Memory Utilization for MTS-12A
6	Memory Utilization for MTS-12B
7	FOCAL-MB2K User Buffer Utilization
8	Special Variables
9	MTS-12 Initialization
10	Core Allocation
11	System Configuration Summary
12	Date and Time Query
13	Levels of Interaction
14	M1INDEX -- An Example of Monitor Usage
15	MODIFY -- Interactive Editing in FOCAL
16	WELCOME -- A FOCAL Program
17	TERMLEARN Initial Frame
18	TERMLEARN Introduction
19	Summary of MTS-12 Features
20	Flow Chart of MTS-12 Monitor

Slide 1
INTRODUCTION

MTS-12 stands for Multi-language, Time-sharing System

for the Digital Equipment Corporation PDP-12 Computer.

MTS-12 consists of a core-resident, time-sharing system utilizing LINCtape which provides many of the advantages of a disc-operated, core-swapping time-sharing system at considerably reduced cost. Since MTS-12 does not require any special hardware, no equipment is rendered obsolete if and when a transition is made to a full scale, disc-operated system.

MTS-12 is entirely compatible with the LAP-6 DIAL Monitor for the PDP-12 computer. Initialization of the MTS-12 system is accomplished simply through the use of a series of interactive displays on the PDP-12 cathode ray tube screen.

Slide 2
COMPARISON OF FOUR TIME-SHARING SYSTEMS FOR THE PDP-12

SYSTEM	LANGUAGES SUPPORTED	LIBRARY CAPABILITY	MAXIMUM NUMBER OF USERS	COST OF SYSTEM*	COMMENT
QUAD	Only FOCAL	No	5	$ 3,300	Rudimentary
LIBRA	Only FOCAL	Yes	7	$ 9,400	Requires non-TSS-12 Compatible Disc
MTS-12	FOCAL, LINC PDP-8#	Yes	6	$ 3,300	Still under development
TSS-12	MULTI-LANGUAGE	Yes@	32	$30,530	Will not support LINC Command Set

* Based on additional equipment required for a four-user system excluding terminals and the $36,900 initial cost of a PDP-12/30.

\# Additional languages can be implemented.

@ FOCAL library capability under TSS-12 is too limited for easy computer assisted educational use.

Slide 3

GROWTH OF A TIME-SHARING SYSTEM

VERSUS MAINFRAME COST PER SIMULTANEOUS USER

Item	Memory * Required	Item Cost	Cumulative Cost **	Number of Simultaneous Users	Cost per User
PDP-12/20	4K	$ 30,000	$ 30,000	1	$ 30,000
Memory Extension Real-time Clock Data Communication Interface	8K	10,000	40,000	2	20,000
TSS-12 Option Memory Extension RF08-RS08 Disc Data Communication Expansion	12K	30,000	70,000	4	17,500
Memory Extension Data Communication Expansion	16K	10,000	80,000	8	10,000
Data Communication Expansion	16K	8,000	88,000	16	5,500

* K = 1000 12 bit words.

** Cumulative Cost does not include the cost of the terminals.

Slide 4

COMPARISON OF MTS-12A AND MTS-12B

	MTS-12A	MTS-12B
Size of User Buffers	1K	2K
Simultaneous FOCAL Users on a 12K PDP-12	6	3
Size of User Programs	1180 characters	1900 characters
Data Storage between Programs	no	yes
Data Storage on LINCtape	no	yes
Character I/O	no	yes

Slide 5

MEMORY UTILIZATION FOR MTS-12A

(See Figure 1, Appendix B)

Slide 6

MEMORY UTILIZATION FOR MTS-12B

(See Figure 2, Appendix B)

Slide 7

FOCAL-MB2K USER BUFFER UTILIZATION

(See Figure 3, Appendix B)

Slide 8

SPECIAL VARIABLES

Number Available:	512 (Two 256 word blocks)
Means of Access:	One file F0 (0-511) or Two files F0 (0-255) and F1 (0-255)
Possible Contents:	Integers in the range -2048 to +2047

Used for Applications Requiring:

1. Large quantities of low precision data
2. Storage of data on tape for later processing
3. Processing of a single set of data by two or more programs
4. Effective branching into the middle of programs
5. String storage (for I/O via FKBD and FTYP)

Slide 9

MTS-12 INITIALIZATION *

MTS-12 INITIALIZATION

MOUNT TAPE CONTAINING
MONITOR ON UNIT 0

THEN TYPE RETURN

* This is a reproduction of the message displayed on the PDP-12 CRT Screen

Slide 10

CORE ALLOCATION *

USER NUMBER	LOCATION
1	CONSOLE
2	DC02-1
3	DC02-2
4	DC02-3
5	DC02-4
6	DC02-5

CORE ALLOCATION--WITH FOCAL

MM 12 FFFF 3333'

Slide 11

SYSTEM CONFIGURATION SUMMARY *

SYSTEM CONFIGURATION

3 4K MEMORY UNITS; FOCAL V

CORE ALLOCATION
MM12 FFFF 3333 NNNN

TAPE DRIVES
0 M 1 S 2 S 3 S
4 E 5 E 6 E 7 E

Slide 12

DATE AND TIME QUERY *

YEAR 19 73
JULIAN DAY 089

24 HOUR TIME:

HOUR 1Ø
MINUTE 55
SECOND 45

* This is a reproduction of the message displayed on the PDP-12 CRT Screen.

Slide 13

LEVELS OF INTERACTION

Level	Usage	Signature
MONITOR	LOGIN, LOGOFF, Resource allocation, loading programs, calling FOCAL	$
FOCAL	Program development, calculator	*
APPLICATION	Interaction with computer for educational, mathematical, and other applications	:

Slide 14

M1INDEX -- AN EXAMPLE OF MONITOR USAGE

```
$ LOAD,Ø,M1INDEX

     ***  M1INDEX  ***

FILE?: 2

                SOURCE          BINARY
  NAME          BN  BLKS        BN  BLKS
CATALOG                         25Ø  1Ø
DATARED                         6ØØ   4
FCOMSET                         51Ø  3Ø
FERRMES                         56Ø  2Ø
FFUNCTNS                        54Ø  2Ø
FOCAL                           47Ø  2Ø
MONITOR                         1ØØ  34
MTS-12                          134  1Ø
TRMLEARN                        2ØØ  5Ø
TRMLRNØ8                        144  3Ø
TRMLRN14                        174   4
T-TABLE                         61Ø   4
T-TEST                          6Ø4   4
TYMSHARE                         6Ø  1Ø
UTILITY                          7Ø  1Ø
WELCOME                         26Ø  1Ø
STAT1                           614   4


$
```

Slide 15

MODIFY -- INTERACTIVE EDITING IN FOCAL

Original Line: 3.Ø5 TYPE 'THIS IS AN ESAMPLE!"

Call Modify: MODIFY 3.Ø5

Revision:

```
T Y P E ' \ " T H I S   I S   A N   E S \ X A M P L E ! "
        ↑ ↑↑                           ↑ ↑↑
1       2 34     5   5                 2 36
```

1. Search character ('), which will not print, is typed. FOCAL prints line through first occurrence of search character.
2. RUBOUT echoes backslash ( ) and deletes character immediately preceding current position.
3. Character(s) to be inserted is typed.
4. To change search characters, a CTRL/G is typed, followed by the new search character(s).
5. CTRL/L is typed to proceed to the next occurrence of the search character.
6. Line Feed is typed to terminate the MODIFY and pick up the rest of the line.

New Line: 3.Ø5 TYPE "THIS IS AN EXAMPLE!"

Slide 16

WELCOME -- A FOCAL PROGRAM

```
*** WELCOME TO MTS-12 ***

ARE YOU USING A TEKTRONICS 4Ø1Ø TERMINAL? (Y/N)

    : N

TO OBTAIN THE FOCAL ASTERISK (*), EXECUTE A CTRL/C MANEUVER.

MTS-12 IS A MULTI-LANGUAGE, TIME-SHARING SYSTEM FOR DIGITAL
EQUIPMENT CORPORATION PDP-12 COMPUTERS DEVELOPED BY
C. S. TIDBALL, B. B. BON, AND J. E. CRAWFORD, III. THE
COMPUTER YOU ARE INTERACTING WITH IS LOCATED IN THE DEPARTMENT
OF PHYSIOLOGY AT THE GEORGE WASHINGTON UNIVERSITY MEDICAL
CENTER IN WASHINGTON, D.C.

FOR ASSISTANCE:  CALL 331-2869 (IF BUSY OR NO ANSWER,
                 CALL 331-6547 OR 331-6548)

WHEN YOU HAVE FINISHED READING THIS MATERIAL, PLEASE
PRESS THE RETURN OR THE CR KEY.

    :

THE FOLLOWING PROGRAMS, AMONG OTHERS, ARE AVAILABLE:

    A.  TERMLEARN -  AN ORIENTATION TO THE COMPUTER TERMINAL
    B.  CATALOG   -  AN INDEX OF MTS-12 LIBRARY PROGRAMS
    C.  FOCAL     -  A BRIEF DESCRIPTION OF THE HIGH-LEVEL
                     COMPUTER LANGUAGE AVAILABLE WITH MTS-12

TYPE THE LETTER PRECEEDING THE PROGRAM YOU DESIRE AFTER
THE COLON (:) BELOW AND PRESS THE RETURN OR THE CR KEY.

    : A
```

Slide 17

TERMLEARN INITIAL FRAME

```
*** TERMLEARN ***

AN ORIENTATION TO THE USE OF COMPUTER TERMINALS
FOR INTERACTION WITH REMOTE COMPUTER SYSTEMS

A TEACHING PROGRAM DEVELOPED BY C. S. TIDBALL
DEPARTMENT OF PHYSIOLOGY
GEORGE WASHINGTON UNIVERSITY MEDICAL CENTER
WASHINGTON, D. C.


*** TERMLEARN *** IS WRITTEN IN SEVERAL SECTIONS TO FACILITATE
RE-ENTRY INTO THE MIDDLE OF THE PROGRAM, IF DESIRED.

TYPE  A  FOR INTRODUCTION
      B  FOR SEND MESSAGE KEY
      C  FOR PAGING
      D  FOR CORRECTING ERRORS
      E  FOR LEVELS OF INTERACTION
      F  FOR CHANGING LEVELS

AFTER THE COLON (:) BELOW, TYPE THE LETTER CORRESPONDING TO
YOUR CHOICE AND PRESS THE KEY MARKED RETURN, OR CR, TO SEND
THAT INFORMATION TO THE COMPUTER.

    : A
```

Slide 18

TERMLEARN INTRODUCTION

```
**  INTRODUCTION  **

    IN ORDER TO COMMUNICATE WITH A REMOTE COMPUTER SYSTEM
BY WAY OF A COMPUTER TERMINAL, THERE ARE FIVE BASIC SKILLS
WHICH MUST BE ACQUIRED:

    1.  CONNECT TERMINAL TO COMPUTER
    2.  SATISFY SIGN-ON REQUIREMENTS AND INDICATE PROGRAM
        TO BE USED
    3.  COMMUNICATE WITH THE PROGRAM
    4.  KNOW HOW TO CORRECT ERRONEOUS INPUT
    5.  MAKE A LEGAL DISCONNECT FROM THE SYSTEM

THE *** TERMLEARN *** PROGRAM DEALS PRIMARILY WITH ITEMS 3
AND 4 FROM THIS LIST.  CONSULT EITHER THE 'GENERAL INSTRUCTIONS
FOR USE OF INTERACTIVE COMPUTER PROGRAMS' OR THE 'PROGRAM
INFORMATION SHEET' FOR DETAILS ABOUT THE OTHER THREE SKILLS.

PRESS THE RETURN, OR THE CR, KEY WHEN YOU ARE READY TO
CONTINUE.

    :
```

Slide 19

SUMMARY OF MTS-12 FEATURES

1. Low initial cost since no special hardware required.
2. Low memory requirement for supervisor (2K).
3. Complete compatibility with LAP-6-MONITOR (DIAL).
4. Simple, flexible initialization sequence.
5. True multi-language capability.
6. Availability of user buffers of different size.
7. Logon by account number and password.
8. LINCtape units may be assigned and released.
9. Availability of complete set of library commands.
10. Utilization Log maintained by system.
11. Compatible with expansion to disc-operated system.
12. Especially well-suited for computer assisted education

Slide 20

FLOW CHART OF MTS-12 MONITOR

(See Figure 1, Appendix A)

APPENDIX A

DECUS Proc.

Spring: 277-285, 1972

MTS-12: A MULTI-LANGUAGE, TIME-SHARING SYSTEM FOR PDP-12 COMPUTERS

C. S. Tidball, J. E. Crawford, III, and B. B. Bon
George Washington University Medical Center
(Telephone 202-331-6547)
Washington, DC

ABSTRACT

MTS-12 is a core-resident, time-sharing system which provides many of the features of a core-swapping, disk-operated, time-sharing system at considerably reduced cost. The system can operate on any PDP-12 equipped with LINCtape, a hardware clock, and appropriate data communication equipment; however machines with increased core memory enable greater system flexibility and can accommodate more simultaneous users. In its present form, MTS-12 is especially well-suited for unattended use of a PDP-12 computer by up to six simultaneous users running pre-tested FOCAL, LINC, or PDP-8 applications programs in the Computer Assisted Education field. The description of the system includes features and liabilities, the architecture of MTS-12, as well as its manner of operation. Utility programs currently available and those under development are identified. The presentation concludes with a discussion of hardware and software modifications which would make the system more efficient for particular categories of use.

INTRODUCTION

MTS-12 stands for Multi-language, Time-sharing System for PDP-12 computers. The system was developed on an 8K PDP-12/30 with a data communication multiplexer interface (DCO2-F), but it can operate on smaller or larger machines. Obviously, machines with larger core memories have greater flexibility and can support more simultaneous users. MTS-12 is multi-language in that it can take advantage of the full PDP-12 capability to support LINC and PDP-8 machine languages providing that all input/output commands are expressed as requests to the MTS-12 Monitor (MONITOR). In addition, for machines with more than 4K of core memory, the availability of a FOCAL interpreter which has a complete set of LINCtape access commands, provides a sophisticated high-level language capability (see Appendix 1). Other languages have not been implemented at the moment, but there is no theoretical limitation to prevent this from being done. MTS-12 is a core-resident, time-sharing system. This means that the executive portion of MONITOR and the User Buffer areas reside in the computer's core memory at all times. Such a design limits the number of simultaneous users which can be accommodated, particularly on machines with limited core memories; but it is considered to be a reasonable compromise since MTS-12 is not dependent on the expensive hardware requirements nor the sometimes inflexible software limitations of a disk-operated, time-sharing system such as TSS-12. In developing MTS-12, a considered attempt has been made to generalize the system for PDP-12 mainframes with differing configurations as well as to anticipate growth and alteration of the system whenever possible.

Motivation for Development

MTS-12 was developed to permit more than one user to have access to a PDP-12 computer at the same time. In particular, it was thought that medical students could benefit from computer assisted education programs which could be made available during evening and weekend hours when the computer might otherwise not be used. The original intent was to make a time-sharing version of FOCAL with a bulk-storage capability on LINCtape. As the system evolved, it was found possible to provide the equivalent of a LINC computer for each user. This enabled processing previously-written, assembly-language programs in the User Buffer areas thus considerably extending the versatility and capabilities of the system. It is recognized that this does not represent an ultimate system and suggestions for future development are incorporated at the end of the presentation.

System Features

Compatibility with the LAP 6-Monitor (DIAL-MS) - Although a number of programming systems are available

for the PDP-12 computer, the popularity and utility of DIAL-MS justified designing MTS-12 around that system. The MONITOR LINCtape for MTS-12 is a DIAL-MS tape in every respect except that tape blocks 270 - 367 which are usually reserved for the DIAL-MS system, contain the MTS-12 system instead. When the system is running, the MONITOR LINCtape runs on Unit 0; during an assembly process this MONITOR LINCtape may be used as a Unit 1 tape. This design is especially helpful for those PDP-12 computers with only two LINCtape units since assembly can be accomplished conveniently by changing the index number of the LINCtape drives without having to remove LINCtapes from the computer.

Simple and Flexible Initialization Sequence - Details of the Initialization Sequence are provided below. The cathode-ray tube screen of the PDP-12 is used, hence there is a rapid and efficient interactive sequence which determines the desired conditions from the available options. The latter have been generalized for computers with up to 16K of core, up to 8 LINCtape drives, and up to 5 input ports on the DCO2-F.

Economy - The MTS-12 system provides considerable time-sharing power for low cost providing that the number of simultaneous users is six or less. Additional economy is also available in that core memory is used efficiently through LINC programming which enables 1K or 2K User Buffers. Finally, since no hardware modifications or additions have been made, no equipment is rendered obsolete if and when transition is made to a full-scale, disk-operated, time-sharing system.

Control of System Resources - There are certain system resources which should only be available to one user at a time, e.g. the DIAL-MS Index of a given LINCtape or the MTS-12 System Log. Other devices may be shared by more than one user, e.g. the LINCtape unit on which the MONITOR LINCtape or a Public Library LINCtape resides. The MONITOR has provisions for assigning and releasing internal devices automatically which means the user is unaware of such transactions. The user may also deliberately assign a logical file for exclusive or shared use. MONITOR then assigns a LINCtape unit to the logical file depending on availability and designations determined during the Initialization Sequence. More than one logical file may be requested and these may also be released. Each user may have a logical file 1 which permits sharing programs which have File 1 library calls. All logical files are automatically released if the user logs off the system. The software to control system resources has been generalized and additional resources may be defined with ease. The control system provides for queuing a device which is temporarily unavailable as well as an indication that a device is unavailable, if such is the case.

Bulk Storage Capability - The DIAL-MS file handling capability has been rewritten so that it can be accommodated under MTS-12. File names may be 8 alphanumeric characters in length but they must begin with a letter. Provisions for saving and deleting binary files from LINCtape are available and these functions may be protected from use by unauthorized persons if desired.

Suitability for Computer Assisted Education - Either through the use of the FOCAL interpreter or by writing programs in assembly language, the MTS-12 system lends itself well to educational applications software particularly if it consists of extensive text display. Since program loading from LINCtape can be accomplished by block number, there is no item limitation as is present in DIAL-MS, FOCAL-12, or TSS-12. For example: it would be entirely feasible to have random access to 1000 multiple choice questions stored on LINCtape under MTS-12. When sequential text processing is occurring, the new sub-program is loaded into core so quickly, if the tape has not been moved in the interim, that the user is generally unaware that there has been a change of sub-programs.

Housekeeping Capabilities - MTS-12 is similar to large-scale time-sharing systems in its logon and logoff functions. The day of the year is kept on a Julian calendar basis (January 1st = day 001); time is provided in hours, minutes, and seconds; and central processor utilization is recorded in seconds to the nearest hundredth of a second. The MTS-12 System Log is kept on LINCtape and thus is available to provide information for such utility programs as System Status or System Utilization. New account codes and passwords may be added to the system easily. MTS-12 is designed to function unattended.

System Liabilities

As indicated previously all input/output commands must be rewritten as MONITOR Requests. This requires program revision before other languages can be implemented. MTS-12 is intended primarily for running pre-tested binary programs or program-development with an interpretive language such as FOCAL that will provide error messages and system recovery. Since there is no KT-12 hardware trap for PDP-8 instructions, a halt command in a user program would cause the computer to stop and remote recovery would not be possible. For the same reason, it is undesirable to permit remote users to run untested assembly language programs when there is no one at the console to restart the system if a fatal error should occur. This is not difficult to control since the remote user is unable to assemble or list such programs under MTS-12. (If considerable program-development is anticipated, modification along the lines suggested in the final section on future development is recommended). The DCO2-F has no provision for carrier-loss disconnect, therefore remote users must break their connection with the computer using the BREAK key on the Teletype terminal. This problem can be obviated by using a newly developed Bell System Data Set, Model 103 G5, which provides automatic reset after carrier-loss. At the moment, no provision exists to prevent a compute-bound program

from monopolizing the central processing unit (CPU); with the kind of processing anticipated this was not considered essential. A clock-driven override could be added to the system if this became a problem.

SYSTEM ARCHITECTURE

The MTS-12 system consists of a MONITOR executive which resides in core-memory, and Systems-Programs which reside on the MONITOR LINCtape. The core requirements of the MONITOR executive were held to 2K by having it automatically load Systems-Programs into the User Buffers to perform MONITOR functions.

Core Allocation

The available core memory is utilized in three possible ways: 2K of memory bank 0 (locations 0000-3777) are reserved for the MONITOR executive; if FOCAL processing is desired, the entire 4K of memory bank 1 are utilized for a 3K FOCAL interpreter and its associated 1K program area; the remainder of core is available for the allocations of individual User Buffer spaces of 1K, 2K, or 4K dimensions.

Number of Simultaneous Users

The number of simultaneous users which can be supported by MTS-12 is a function of three variables: the amount of available core, the nature of the user processing, and whether or not the FOCAL interpreter is required. In Table 1 can be found a summary of these relationships.

TABLE 1

Amount of Core	Nature of Processing LINC	PDP-8	Available FOCAL	Max. No. of Simultaneous Users
4K	YES	NO	NO	2
8K	YES	NO	YES	2
8K	YES	YES	NO	3 - 6 *
8K	YES	NO	NO	6
12K	YES	YES	YES	3 - 6 *
12K	YES	NO	YES	6
12K	YES	YES	NO	4 - 10 *†
12K	YES	NO	NO	10 †

* Depends on size of PDP-8 program. Only one PDP-8 program can be accommodated per memory bank (requires location 0000); but if the entire 4K is not required, LINC or FOCAL Users may be accommodated in the same bank.

† Implementation beyond 6 users is theoretically possible but not available in the current version.

Systems - Programs

MONITOR functions are performed by Systems-Programs which reside on the MONITOR LINCtape and are automatically loaded into the User Buffers by the MONITOR executive. These Systems-Programs have been divided into segments so that each will run in 1K of core, the size of the smallest User Buffer. The Systems-Programs with their functions are detailed below.

MONITOR Command Interpreter A - loaded when CTRL/S is typed, begins User Processing. A $ is typed by this segment to indicate that MTS-12 is ready to accept Monitor Commands from the location which requested to begin User Processing. This segment interprets all Monitor Commands except LOGON and LOGOFF. The complete MONITOR Command vocabulary may be found in Appendix 2.

MONITOR Command Interpreter B - loaded after first request for Monitor. This segment interprets LOGON, validates the account code and password, types a Welcome Message, and also processes the LOGOFF with its summary of terminal time and CPU utilization.

DIAL Index Processor A - locates, deletes, or updates a DIAL Index.

DIAL Index Processor B - finds space to save a file; the resident Monitor recalls the DIAL Index Processor A automatically to store the starting location and the length of the file on the DIAL Index.

FOCAL Processor A - enables user to have access to the FOCAL interpreter.

FOCAL Processor B - creates an overlay for FOCAL, 1969 to provide LINCtape availability and to make it suitable for MTS-12 operation.

FOCAL Processor C - calls the DIAL Index Processors to implement FOCAL-MTS library commands on LINCtape.

System Loader - loads and begins execution of a binary program whose location and length are correctly identified in a DIAL index of a LINCtape.

Error Recovery - provides system recovery after a request for an illegal LINCtape operation.

SYSTEM OPERATION

The core-resident MONITOR executive performs three major functions: it services all interrupts, it accomplishes switching from one user to another, and it handles resource allocation. The remainder of this section is organized around the four types of processing which take place during MTS-12 operation. The reader is referred to Figure 1 for a generalized flow chart of the operation of the MTS-12 MONITOR.

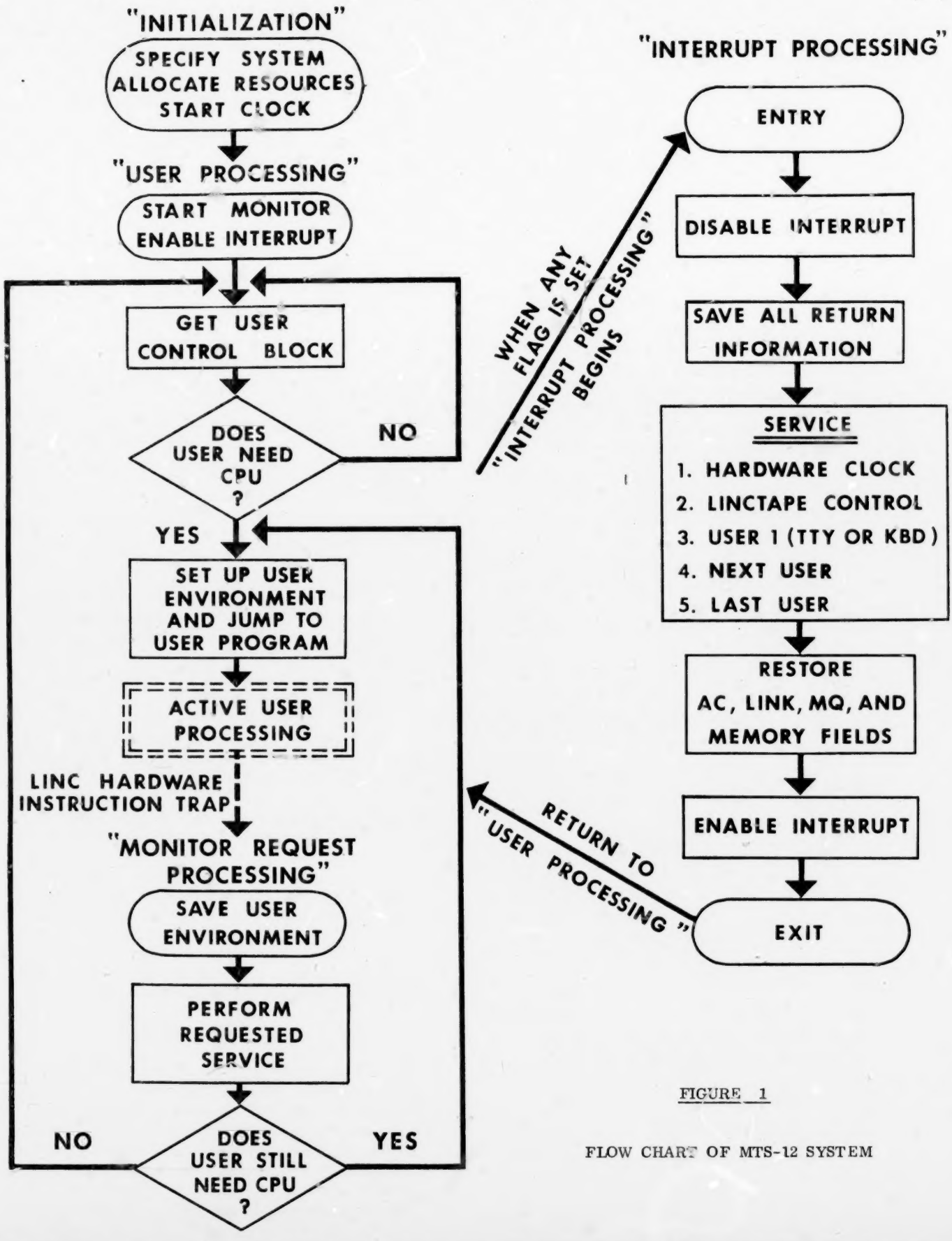


FIGURE 1

FLOW CHART OF MTS-12 SYSTEM

User Processing

Let us now consider the sequence of events when a user desires computational services under MTS-12. When the user holds down the Control key and momentarily presses the S key (CTRL/S), the computer immediately echoes ↑ S (other Control functions are described in Appendix 2). Then after a short delay, a CRLF is executed and MTS-12 types a $ which indicates that the system is ready for an MTS-12 command. This means that a User Buffer has been assigned and that the Systems-Program MONITOR Command Interpreter A has been loaded into the User Buffer area. If the MONITOR LINCtape is close to the location of the MONITOR Command Interpreter A binary file, then the response time of MTS-12 will be on the order of 1 or 2 seconds. On the other hand, if the MONITOR LINCtape is spinning as a result of another user's request, the delay may be as long as 20 - 30 seconds. The MONITOR Command Interpreter A next notes that the user has not yet logged on, therefore it automatically overlays the contents of the User Buffer with the Systems-Program MONITOR Command Interpreter B. The echo is defeated to preserve the confidentiality of the logon information and if the user's logon sequence as well as his account code and password match those previously stored on the MONITOR LINCtape, MTS-12 will respond USER 1 LOGGED ON and give the date and time of the transaction. Note that the console teletype machine is always associated with User 1 (see Figure 3). After this a brief Welcome Message is typed which reminds the user of the principle MTS-12 commands and provides a telephone number in case he should experience difficulty. The Welcome Message can easily be altered and thus provides a convenient way of making system announcements. (The message can also be interrupted at any time by typing CTRL/S.) Now if we add a second user, we can demonstrate the nature of the time-sharing operation. Let us suppose that MTS-12 is still typing the Welcome Message for User 1 when a CTRL/S is executed by User 2. There is no delay in echoing ↑ S for the new user in spite of servicing User 1 because the CPU is spending much of its time waiting for the User 1 teletype to set its flag indicating that it has finished printing a character. Similarly, the MONITOR executive interprets the CTRL/S and loads the appropriate Systems-Program into the assigned User Buffer for User 2. The sharing is made possible because each user program relinquishes control of the CPU when it issues a MONITOR Request command to perform an input/output operation. The program regains control of the CPU when its input/output operation is completed. Now let us return to User 1 who has completed his Welcome Message and received a new $ indicating that MTS-12 is ready for a command. If he wishes to run a FOCAL program entitled MEDTEACH stored on the LINCtape mounted on unit 1, the following steps would be required. He would type ASSIGN, 1, 1, SHR and the computer would respond FILE 1 = UNIT 1. This means that logical file 1 for User 1 has been assigned to LINCtape unit 1 for shared use. Had the user merely typed ASSIGN, 1 the computer would have responded FILE 1 = UNIT 4 because unit 4 was the lowest LINCtape unit number designated for exclusive use during the Initialization Sequence. MTS-12 automatically provides a new $ after processing such a command and the user need only type FOCAL to activate the FOCAL interpreter. At this point the computer will type an * to confirm that the user may execute FOCAL commands, and his program will be loaded with a LIBRARY GO command which takes the form L G, MEDTEACH, 1. Note the need to specify the logical file number at the end of the command so that MTS-12 knows which LINCtape unit to go to in order to retrieve the program. The LIBRARY GO command, since it requests input from tape, eventually is interpreted as a MONITOR Request command to perform input/output and this initiates MONITOR Request Processing. Before discussing that subject, it would be helpful to describe the User Control Block (UCB). The UCB is a 20_8 word register which contains the information necessary for the MONITOR executive to dispatch and control the program running in the User Buffer. There is a permanent storage area for each UCB and an ONDECK area (locations 0113-0132 in page 0 of memory bank 0) where the UCB of the Active User resides while he is being processed. Word number 6 of the UCB provides software status flags to indicate the nature of the processing and the possible input/output wait states.

MONITOR Request Processing

Because the standard PDP-12 is only able to trap instructions from the LINC command set, the computer must be in the LINC operating mode before a MONITOR Request command is issued. These commands have been created from the available undefined instructions in the LINC command set, and only 14_8 such commands have been implemented in the current version (0540 - 0553). A complete description of the commands can be found in Appendix 3. There is ample room to accommodate additional commands for computers with different configurations. As these special commands are trapped and interpreted, the interrupt facility is disabled (Not shown on Figure 1) and the Active User environment is saved. Now the MONITOR executive performs the requested service for the Active User. Some MONITOR Request Commands, such as enqueing a resource, are executed immediately and the Active User regains control of the CPU; commands involving input/output transfers generally place the Active User in a Wait-State until the operation can be completed. This is accomplished by setting a flag in the UCB which enables the MONITOR executive to transfer control of the CPU to the next eligible user. When the input-output operation is completed, Interrupt Processing begins and clears the user's UCB wait flag, thereby making him again eligible for CPU control.

Interrupt Processing

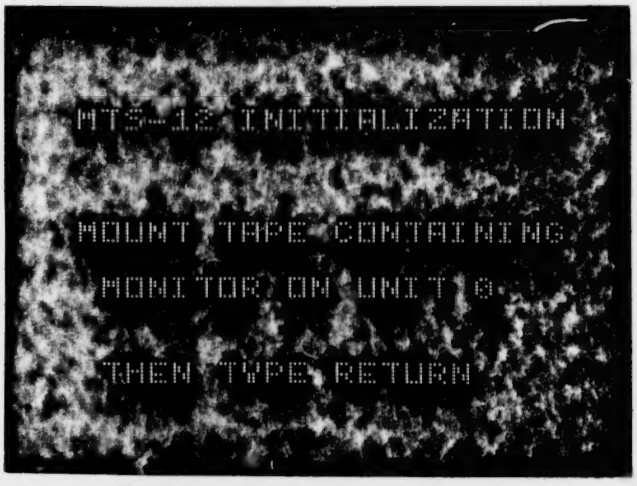
During Active User Processing the Interrupt Facility is enabled and the setting of a hardware flag will cause the computer to enter Interrupt Processing. The Interrupt Facility is disabled and the contents of

registers needed to return to User Processing are saved. The interrupt is serviced by the MONITOR executive in the sequence indicated in Figure 1. More than one service may be performed during a given Interrupt Processing sequence. After restoring the Active User environment, the Interrupt Facility is re-enabled and the CPU returns to the location in the Active User program which was interrupted.

Initialization Sequence

Since MTS-12 has been generalized to conform to different PDP-12 configurations as well as different User Processing requirements, it is necessary to specify these as the system is started. In actual practice the MONITOR LINCtape is mounted on a LINCtape drive which is designated as Unit 1. Any DIAL-MS LINCtape is then mounted on a LINCtape drive designated as Unit 0. DIAL-MS is brought into core in the usual fashion, and the MTS-12 system is loaded from the Unit 1 LINCtape after requesting the command mode of DIAL-MS. MTS-12 is a self-starting program and the display (Figure 2) shown below appears on the CRT screen to begin the Initialization Sequence. This frame remind the user that he must change the index numbers on the LINCtape drives before proceeding. The second frame provides a choice of System Configuration. A

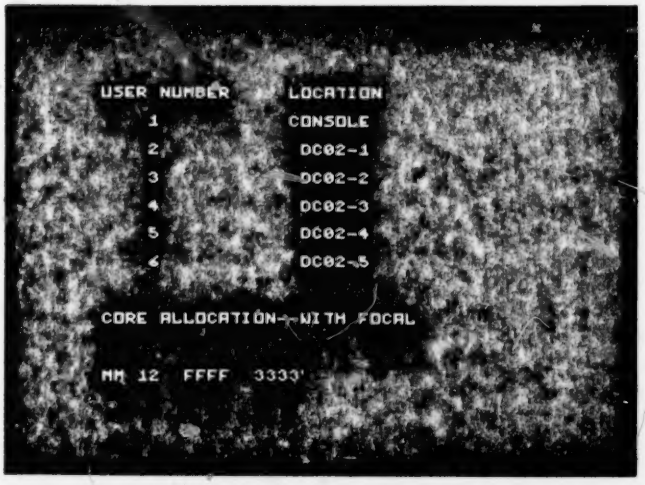
FIGURE 2



First Frame of Initialization Sequence

standard configuration is stored on the MONITOR LINCtape and may be requested; this moves the user directly to the sixth frame which consists of a summary display (Figure 4). Alternatively, the user may specify a temporary configuration or designate a replacement for the standard configuration. Either of these two options takes the user through the entire Initialization Sequence. The third frame performs two functions: to establish the number of 4K memory banks available on the particular PDP-12 computer (1 - 4 are permissible in the current version) and to determine whether or not the FOCAL interpreter will be utilized. The fourth frame identifies the locations for the permanently assigned user numbers (Figure 3). User Number 1 is always

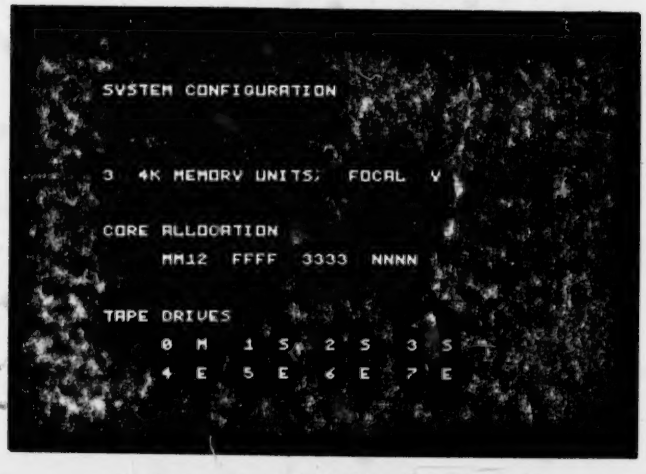
FIGURE 3



Fourth Frame of Initialization Sequence

the console teletype machine; the other user numbers are assigned to input ports on the DCO2-F. This frame is also used to allocate the core memory. If the FOCAL interpreter has been requested, four F's will appear in the spaces for the 1K units in memory bank 1. Similarly, two M's appear automatically in the first two 1K units of memory bank 0 for the MONITOR executive. The number of units to be allocated is based on the answer specified in response to the query in the third frame, and digits are used to indicate the individual User Buffers. In the example shown which presumed a 12K machine, User Numbers 1 and 2 each have 1K User Buffers and User Number 3 has a 4K User Buffer in memory bank 2. The fifth frame is concerned with designating LINCtape drive unit numbers for shared or exclusive use. Unit 0 is reserved for the MTS-12 MONITOR LINCtape. All other units are assigned shared or exclusive use status without regard to the number of units physically on the computer. Thus it is possible to change the status of a unit by changing its unit number without having to reinitialize MTS-12. The sixth frame is a summary

FIGURE 4



Sixth Frame of Initialization Sequence

statement of the configuration requested; the four N's under core allocation indicate that memory bank 3 is not available for the example shown (Figure 4). The final frame enables the user to designate the last two digits of the year, the day, and the time as previously described. Pressing the Line Feed key after completing the queries, starts the clock and MTS-12 is ready for use.

SOFTWARE DEVELOPMENT

Since MTS-12 is not running all the time in our facility, a user may have a both time-sharing and stand-alone programs on a given LINCtape. To help identify operating systems, languages, and buffer size requirements a set of conventions has been adopted. An M as the first letter of a program name indicates that the program is to be run under MTS-12. The second character identifies both the size of the User Buffer as well as the language according to the following code: 1 and 2 refer to LINC programs of 1K or 2K dimensions respectively, 4 refers to a PDP-8 program which requires the lowest 1K segment of a 4K bank and generally utilizes the remainder of the bank, and $ refers to FOCAL programs which require the availability of the FOCAL interpreter as well as a 1K User Buffer.

Utility Programs Available

M1INDEX - This program first requests the logical file number of an assigned file and then prints the DIAL Index for the LINCtape mounted on the unit number associated with that logical file.

M1SYSIN - This program provides a short description of the MTS-12 system including the complete set of MONITOR Commands as in Appendix 2.

M1WRITE - This program generates line numbers, accepts keyboard input, stores it in the specified blocks of a LINCtape, and lists the input as required. Note: rubout is available but no other editing, therefore this program will probably be replaced by M2WRITE (see below) as soon as it becomes available.

M$INTRO - This five part program entitled "Introduction to MTS-12" illustrates the computer assisted education capabilities of FOCAL running on the MTS-12 system. Note: the first part of this program may be used to orient persons who have not previously used a teletype machine.

MTS-SIM - This program does not run under MTS-12 but provides a way of debugging MTS-12 LINC programs under DIAL-MS when the MTS-12 system is not running.

Demonstration Programs

M1DEMO - This program displays text on the PDP-12 cathode ray tube screen. It was developed to demonstrate access to PDP-12 analog capabilities under MTS-12.

M4DEMO - This program accepts keyboard input, stores it, and retypes it when a period is encountered. It was developed to demonstrate the ability of MTS-12 to run modified PDP-8 programs.

M$ANIMAL - This program is a limited version of the PDP-10 "Guess the Animal" program. It has a fixed capacity of sixteen animals but is useful to demonstrate the interactive capabilities of FOCAL running under MTS-12.

Programs Under Development

M2EDITOR - This program is the MTS-12 equivalent of the PS/8 Editor. It is intended to facilitate the entry of a symbolic program in either PDP-8 or LINC in nemonics. The program is stored in the DIAL Source Working Area of the assigned LINCtape from whence it can be assembled under DIAL-MS without further manipulation. Note: under these circumstances, if the MONITOR LINCtape is used as the Unit 1 LINCtape during the assembly process, the binary will be stored into core by an MTS-12 LOAD command. Alternatively, the binary can be moved to the DIAL Program Storage area of any specified LINCtape as a named file, from whence it can be run under MTS-12 by calling it into core either by its name or tape block location.

M2WRITE - This program is similar to M1WRITE except that a full editing capability patterned after the PS/8 Editor, is included.

M1SYSTAT - This program provides the current status of the MTS-12 system including the number of users signed on and the nature of their current processing.

M$OTM - This program entitled "Orientation to Medline" is a teaching program which enables a person to learn how to use MEDLINE, the computerized citation retrieval service of the National Library of Medicine.

M2CSSES - This program entitled "Computerized Student Self-Evaluation System" enables a student to interact with the computer in the following way: a subset of the question file is selected by the student; twenty questions are selected at random by the program and then displayed sequentially; the student is given an opportunity to respond to each question; and at the end of the last question, the student is given a percentage correct score and the item numbers of the questions answered incorrectly. Because of the randomization feature, each self-evaluation test differs from preceding ones.

M2SSEAM - This program entitled "Student Self-Evaluation: Author Mode" provides a conversational dialogue to assist faculty members in creating question files on LINCtape to be used in the preceding program.

MTS-U - This program unloads the MTS-12 System Log stored on the MONITOR LINCtape and provides records of utilization by account code. The program is intended to run under DIAL-MS.

FUTURE DEVELOPMENT

It is not easy to guide future development in the absence of clearly identified goals for a computational system, but perhaps our situation is sufficiently complex to provide a useful, illustrative example. In this environment three categories of use compete for the PDP-12: a) general purpose computing including student program development under the DIAL-MS operating system, b) time-sharing for computer assisted education and remote activities such as patient interviewing, and c) neurophysiologically-oriented, analog processing. Each of these categories of use seem to require the entire machine; certainly MTS-12 in its present form could not easily support program development without rewriting the LINC and PDP-8 assemblers and there would still be the problem of crashing the system when flawed programs were tested. Similarly, it seems unlikely that MTS-12 or even TSS-12 would be compatible with the high frequency sampling requirements of neurophysiological processing. Two alternate philosophies toward resolving the dilemma of competing users are available: either to have three dedicated computers or to develop a multi-processor network. The former choice is simpler but more costly, especially if each machine is to be similarly outfitted with expensive peripheral devices. The latter is on the frontier of minicomputer development and thus both hardware and systems-software problems still abound. An additional factor to be considered which undoubtedly dismays owners of PDP-12 mainframes, is the discrepancy between hardware costs for the PDP-12 series when compared to the current prices of PDP-8/e components. Therefore in our situation we are considering a compromize designed around an 8K PDP-8/e with the recently announced 1.6 million word floating-head, disk-cartridge file. Although the latter would probably not be fast enough for core-swapping with many users, it might still be satisfactory for up to six simultaneous users. A fixed-head disk could always be added if this were found to be essential, and a line-printer would ease the burden of listing lengthy programs at the console teletype machine. The availability of the PDP-8 instruction trap as part of the extension of memory to 8K will encourage us to rewrite MTS-12 in PDP-8 code. This should then make it possible to adapt, with little or no modifications, programs developed for use on the TSS-8. With suitable design, it may even be possible to create the equivalent of a time-sharing OS/8 system, although this will probably require additional core. In time the PDP-12 will be included through some sort of interprocessor link, in order for it to utilize the new peripherals; but in all likelihood, the ability of the two processors to work independently will be preserved so as to retain the flexibility needed to provide three categories of service, with only two processors, at minimum cost.

ACKNOWLEDGEMENTS

The development of MTS-12 was supported in part from the following resources:

Intramural funds of the Department of Physiology
National Science Foundation GB-7761
U.S. Public Health Service 5 SO1 RR 5359
Social Rehabilitation Service 16 P 56803

APPENDIX 1

FOCAL Library Commands Available under MTS-12

Command	(Usage)	Meaning
Library Load	(L L, PROGNAME, 1)	Load named file from LINCtape unit assigned to designated logical file.
Library Go	(L G, = XXXX, 1)	Load and begin execution of program stored in tape block number XXXX.
Library Save	(L S, METEACH, 1)	Save named file on LINCtape unit assigned to designated logical file.
Library Delete	(L D, COMPED, 1, ABC)	Delete file protected with password ABC from DIAL Index of LINCtape unit assigned to designated logical file.

Note: Files may be read by all users unless a LINCtape unit is assigned for exclusive use. The only file protection provided is that which prevents saving or deletion of files by unauthorized users.

APPENDIX 2

MTS-12 MONITOR Control Functions

In the current version four control functions have been implemented. CTRL/R prevents the MONITOR from echoing characters automatically as they are typed on the keyboard, and CTRL/T restores the echo if it has been disabled. CTRL/C interrupts a FOCAL program and restarts FOCAL; CTRL/C is ignored if the user is not in FOCAL mode. CTRL/S is used to obtain the command mode of the MTS-12 MONITOR. Since it is always legal, it may be used at any time to interrupt a user program. However, it should be recognized that CTRL/S replaces the contents of the User Buffer with the Systems-Program MONITOR Command Interpreter A, therefore losing any user input, program or data, that has not previously been saved on LINCtape.

MTS-12 MONITOR Commands

ASSIGN, 1 - Assign logical file 1 to an available LINCtape for exclusive use.
ASSIGN, 2, 3, SHR - Assign logical file 2 to LINCtape unit 3 for shared use.
FOCAL - Enable access to the FOCAL interpreter.

LOAD - Load program from binary working area of logical file 0 (= unit 0) and start at location 20.
LOAD,2,132 - Load self-starting binary program which begins with header block in block 132 of LINCtape unit assigned as logical file 2.
LOAD,1,PROGNAME - Load self-starting program called PROGNAME from LINCtape unit assigned as logical file 1.
LOGOFF - Log the user off MTS-12.
LOGON,XXX,YYY - Log user with account number XXX and password YYY onto MTS-12.
RELEASE,1 - Release LINCtape unit assigned to logical file 1.

APPENDIX 3

MTS-12 MONITOR Request Commands

MONITOR Request Commands (MRCs) are trapped, LINC mode instructions with values between 0540 and 0553. Their functions are briefly described below.

MRC 0(0540) - Return to user with interrupt off and user control block ONDECK.
MRC 1(0541) - Output one ASCII character to user's TTP.
MRC 2(0542) - Place program in a wait state to allow other users to obtain CPU time.
MRC 3(0543) - Perform LINCtape read or write with normal return.
MRC 4(0544) - Perform LINCtape read or write and branch to location specified by AC.
MRC 5(0545) - Input one ASCII character from user's KBD.
MRC 6(0546) - Enqueue a system resource and skip if successful.
MRC 7(0547) - Dequeue a system resource.
MRC 10(0550) - Same as MRC 2 except that return is made to the location specified by the AC.
MRC 11(0551) - Return the absolute unit number assigned to the logical file number specified by the AC.
MRC 12(0552) - Return the date and time to the user.
MRC 13(0553) - Skip on instruction if any character has been received from the user's KBD.

APPENDIX B

MTS-12 REVISITED: POWERFUL INTERVIEWING CAPABILITIES FOR THE PDP-12 THROUGH AN IMPROVED TIME SHARING FOCAL

DECUS Proc.
Spring: 85-88, 1973

Charles S. Tidball and Bruce B. Bon
George Washington University Medical Center
(Telephone 202-331-6547)
Washington, DC

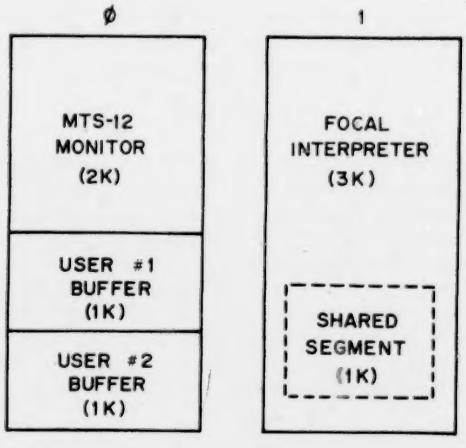
ABSTRACT

MTS-12 is a low-cost, core resident, time-sharing system with program storage on LINCtape. A compatible FOCAL interpreter provides a high-level language capability which is somewhat limited in the original version (MTS-12A). The new version (MTS-12B) incorporates larger user buffers (2K) with special variables storage outside the area used for program storage. The FOCAL interpreter has been enlarged by eliminating the need to move the user's program area into the bank of core containing the interpreter. A number of new commands have been implemented which render this version of FOCAL similar to FOCL/F and FOCAL-10. Two new functions, FTYP and FKBD, provide a rudimentary string handling capability which in combination with the special variable feature, makes it possible to store data generated at remote terminals for subsequent analysis or processing. Thus MTS-12B is suitable for use in patient interviewing, computer generated interview summaries, and similar sophisticated tasks in computer assisted education. The presentation includes an analysis of advantages and limitations of the new version as well as an indication of the direction expected for future developments.

INTRODUCTION

MTS-12, a Multi-language, Time-sharing System for PDP-12 computers, was first introduced at the Spring DECUS Symposium, 1972. That version of the system, now called MTS-12A, met design specifications for a low-cost, core-resident, time-sharing system with program storage on LINCtape. The tape index, tape format, and file structures are compatible with the LAP-6 Monitor (DIAL-MS). User buffers consist of one thousand (1K) words and a high-level language capability is provided through a 3K FOCAL interpreter. The User Buffer is swapped into the 4K memory bank containing FOCAL for interpretation of FOCAL instructions. Since the core resident portion of the MTS-12 monitor only requires 2K of memory, an 8K PDP-12 can support up to six simultaneous users for pre-tested LINC application programs when FOCAL is not in use. If the high-level language interpreter is available, an 8K machine can support two simultaneous users (see Figure 1). Other language interpreters or compilers could be used with MTS-12A but have not yet been implemented.

FIGURE 1



Memory Utilization for MTS-12A

Motivation for Further Development

Patient Interviewing - In order to take a patient history, a computer system must be able to accept and store strings of characters such as the patient's name. It must also be able to interpret responses and branch accordingly. In addition, a data storage capability on some bulk storage device is desirable in order to save the history, regenerate it at a later time, or create a summary of the interview for inclusion in the patient's

chart. FOCAL-MA1K, the version of FOCAL developed for MTS-12A, is totally inadequate for these tasks because a) string input is hashed into a form which cannot be regenerated, b) the program buffer is small and nothing can be retained between chained programs, and c) all data is stored only in core and cannot be transferred to LINCtape. FOCAL-MB2K, the new time-sharing FOCAL, incorporates changes which overcome these limitations.

Computer Assisted Education - The features mentioned above are all desirable for use in educational programming as well. Furthermore, the acquisition of a Tektronics 4010 graphic display terminal made possible many additional applications provided that the system could support that terminal's capabilities.

MTS-12B

Several changes have been made in the time-sharing system to make using it more convenient and to make the LOGIN format similar to that of the commercial TYMSHARE network. The system LOGIN program requires the user to input an account number, a pass word, and a zero to four character project code. The project code is stored in the log and may be user initials or anything else that may be desired. When the LOGIN is complete, the system automatically starts FOCAL and loads the FOCAL program named WELCOME. Since WELCOME is a FOCAL program, it may be altered easily whenever needed and the MONITOR mode of operation is rendered transparent to a high-level language user.

Two tape units are automatically assigned for shared use but may be released and reassigned from the MONITOR mode of operation. One of the preassigned tape drives contains a System Library of useful FOCAL programs, and the other contains a series of programs related to patient interviewing.

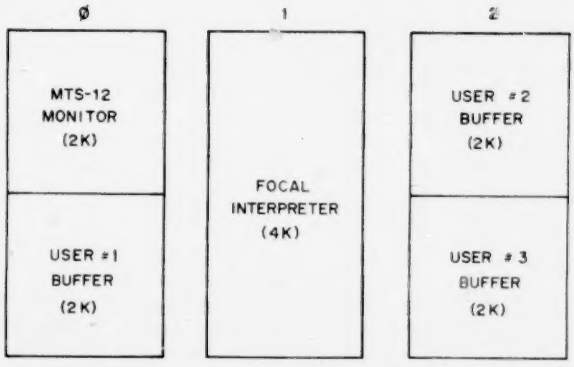
FOCAL-MB2K

In order to be able to expand FOCAL to meet our needs, it was decided that the user program would not be swapped in and out of the interpreter, but would remain in the user buffer. This required implementation of a time-consuming accessing method for FOCAL, but freed about 1K in the interpreter for new functions and commands (see Figure 2). The user buffer was expanded to 2K, allowing a full 1K for the FOCAL storage area and 1K for reentry information, special variables, and the FOCAL library processor.

New Features

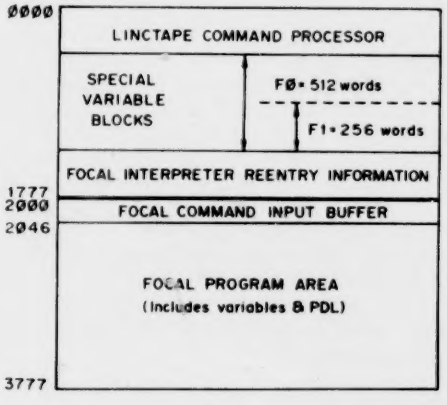
Special Variables - Two blocks or 512 words of special variable storage are provided in the user buffer (see Figure 3). The function F0 allows access to any word in the storage area and requires a subscript in the range 0-511; the function F1 allows access to the second block only and requires a subscript in the range 0-255 (e.g. F0(258) is equivalent to F1(2)). This allows the user to treat the storage area either as one 512 word file or as two 256 word files. As in FOCAL-12, F0 and F1 may be used on the left side of an equal sign or as arguments in an ASK command, as well as in arithmetic expressions. Each special variable occupies a single 12-bit word in memory and is treated as a signed integer with a range of -2048 to +2047. When values are assigned to special variables, fractional parts are dropped as well as overflow above the 12-bit word size. The sign bit will be set negative for numbers between 2048 and 4095, and the special variable will contain the intended value minus 4096. For any value outside of the normal range, the value stored will differ from the assigned value by an integral multiple of 4096.

FIGURE 2



Memory Utilization for MTS-12B

FIGURE 3



FOCAL-MB2K User Buffer Utilization

VARIABLES Commands - The VARIABLES SAVE command is used to save on LINCtape either variable block or both together. Similarly, the VARIABLES GET command is used to read variables from LINCtape into core. VARIABLES DELETE erases a variables file name from the DIAL-MS index.

PROGRAM Commands - The LIBRARY commands of FOCAL-MA1K have been converted to PROGRAM commands to be consistent with FOCAL-10 and FOCL/F. The new commands are PROGRAM SAVE, PROGRAM GET, PROGRAM RUN, and PROGRAM DELETE. See the Appendix for formats and examples of VARIABLES and PROGRAM commands.

FKBD and FTYP Functions - The FKBD function may be used for single character input. It returns the decimal value of an 8-bit character received from the user's keyboard. Similarly, the FTYP function sends the right-most 8 bits of the argument to the user's printer as a single character.

Advantages

Data Retention Between Chained Programs - Because the special variables are not in the main FOCAL storage area, they are not altered in any way when a PROGRAM command is executed. This allows several programs to operate on the same set of data. Also, by setting the value of a special variable before a PROGRAM RUN command and testing that variable in the first statement of the new program, an effective branch into the middle of the new program may be accomplished.

Data Storage on LINCtape - Using the VARIABLES commands, data may be stored on or retrieved from LINCtapes. This data may be numeric data or string data input with the FKBD function.

Rudimentary String Handling - Because the FKBD function inputs characters as their numeric codes, the program may manipulate the resulting numbers arithmetically. While this is not the most convenient system for handling strings, it is completely flexible since string manipulation is totally the programmer's responsibility.

Specialized Input/Output - For terminals which have special characters such as clear-scope, back-space or underline, the FTYP function may be used to print the special characters. Graphics terminals and plotters require encoding of coordinates into characters which may be sent by the FTYP function. Similarly, graphics input may be accomplished with the FKBD function.

Relation to Interactive Computing - For computer assisted education, FOCAL-MB2K allows the implementation of a sequence of programs which identify the student, instruct him, test him, and store his answers and comments on tape. Programs could be written in FOCAL to analyze student performance. Patient interviewing programs have been written which input and store information entered by the patient or clinic personnel. A FOCAL-MB2K graphics package has been developed using the FTYP and FKBD functions, to support the Tektronics 4010 storage scope terminal. This combination provides both graphic input and output for either research or educational uses.

Limitations

FOCAL-MB2K requires 2K for each user buffer plus 2K for the MTS-12B Monitor and 4K for the FOCAL interpreter. This means that 12K of core memory will support 3 FOCAL-MB2K users versus 6 FOCAL-MA1K users. Because of the memory accessing method used in FOCAL-MB2K, the CPU time required for running FOCAL programs has been increased. This does not slow down the speed of interactive programs, but could seriously affect the speed of compute-bound programs. The file structures of FOCAL-MA1K and FOCAL-MB2K programs are slightly different, so that programs written in one version may not be run in the other version except by outputing onto paper tape and inputing the paper tape back into the other system.

In order to keep the programming as simple as possible, a single data format was chosen for the special variables. The 12-bit integer format, while providing the largest amount of storage for non-packed ASCII text, is not suitable for complex mathematics. String manipulation, while completely flexible, is tedious and time-consuming on the part of the programmer.

FUTURE DEVELOPMENT

In the immediate future, MTS-12B will be altered to be compatible with the DEC RT02 data entry terminal. This will allow technicians to run FOCAL-MB2K programs which will accept patient laboratory data for storage on LINCtape.

Development is to begin shortly on a new time-sharing system for a PDP-8/E computer with RK-8E 1.6 megaword disk. We are committed to developing a version of FOCAL similar to FOCAL-MB2K which will run on that system. Additions to that FOCAL will presumably include more sophisticated string I/O and string functions, as well as file access by file name stored in a string. It is expected that disk operation will increase the speed of many operations which formerly were slowed down by reading in programs or data from LINCtape. There is also the possibility that eventually the number of simultaneous users will be increased by utilizing a swapping algorithm for user buffers rather than keeping them all resident in core simultaneously. Finally, it is expected that 4K user buffers will be available so that programs previously developed for a stand-alone PDP-8 or the TSS-8 time-sharing system should be able to run, in time-sharing, on our new system.

ACKNOWLEDGEMENTS

Continued development of MTS-12 and FOCAL-MB2K was supported in part by the following resources:

Intramural funds of the Department of Physiology
Social Rehabilitation Service 16 P 56803
Social Rehabilitation Service 16 P 57538

It is a pleasure to acknowledge the support and assistance of the following individuals:

John Alderman - a consistent advocate of the computer language FOCAL
Douglas Wrege - the originator of FOCL/F
R. P. Warnock III - the creator of FOCAL-10

APPENDIX

VARIABLES and PROGRAM Command Summary

Command	(Usage)	Meaning
PROGRAM GET	(P G PROGNAME 1)	Load named file from LINCtape unit assigned to designated logical file.
PROGRAM RUN	(P R =XXXX, 1)	Load and begin execution of program stored in tape block number XXXX.
PROGRAM SAVE	(P S PROGNAME 1)	Save named file on LINCtape unit assigned to designated logical file.
PROGRAM DELETE	(P D PROGNAME 1,ABC)	Delete file protected with password ABC from DIAL index of LINCtape unit assigned to logical file 1.
VARIABLES GET	(V G 0 DATA 3)	Read the 1-block file named DATA from logical file 3 into the first block (F0) of the special variables buffer.
VARIABLES SAVE	(V S 2 =100,1)	Save both special variables blocks as a 2-block file starting at block 100 of logical file 1.
VARIABLES DELETE	(V D DATA 1,ABC)	Delete file protected with password ABC from DIAL index of LINCtape unit assigned to logical file 1.